While the concept of IA involves various online activities including gaming and e-mail, IA is generally defined as a maladaptive preoccupation with Internet use that interferes with everyday life. Such behavior frequently accompanies a set of clinical symptoms similar to substance use disorders, like mood modification, salience, impaired tolerance, social withdrawal, and conflict. Symptoms are recurrent in nature, and IA leads to significant impairment in personal, social, and occupational functioning and multiple facets of well-being. Especially, IA in children and adolescents is of great social concern.

While the concept of IA involves various online activities including gaming and use of social networking services (SNS), Diagnostic and Statistical Manual of Mental Disorders (DSM) version 5 (DSM-5) includes Internet Gaming Disorder (IGD) as a specific form of IA. However, IA is linked to various online activities and the degree of psychological distress. This indicates the importance of comprehensive assessment of online behavior and psychological factors for further understanding of IA.

Keywords: depression, Internet addiction, Internet gaming disorder, psychological distress, students

Introduction

The Internet changed our daily life across the world. Today, many people work, learn, shop, and even interact with each other online. Although the beneficial impact of the Internet is huge, problematic usage of the Internet gathers public attention, leading itself to a research topic in psychiatry. The concept of Internet addiction (IA) or problematic Internet usage is proposed, yet its validity as diagnostic entity is still debated. IA is generally defined as a maladaptive preoccupation with Internet use that interferes with everyday life. Such behavior frequently accompanies a set of clinical symptoms similar to substance use disorders, like mood modification, salience, impaired tolerance, social withdrawal, and conflict. Symptoms are recurrent in nature, and IA leads to significant impairment in personal, social, and occupational functioning and multiple facets of well-being. Especially, IA in children and adolescents is of great social concern.

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Mental Disorders, Fifth Edition, proposed the concept of Internet Gaming Disorder specifically focusing on addictive behaviors in online gaming. However, it still remains largely unknown how various online activities are linked to disturbances in real life.

How individuals engage in online activities may reflect multiple factors such as social background and relationships, and psychological and cognitive functioning. Many theoretical models of IA were proposed. Brand et al proposed that certain personality factors, psychopathological symptoms, and social cognitions would predispose IA in the presence of mediating factors like dysfunctional coping styles and Internet use expectancies. Dong and Potenza introduced a model that connects Internet gaming disorder with cognitive functioning, such as decision-making style, executive control, stress relief, and reward sensation on craving for IA.

Several studies examined how IA is related to clinicodemographic factors including age, sex, anxiety, and depression. These factors involve clinical factors such as psychological symptoms and disorders including anxiety and depression, and demographic factors such as age and sex. For example, one study on university students in the United States, China, and Singapore showed that male students were more addicted to games, while female students were more addicted to SNS. These results may suggest that age and sex indirectly affect IA via differential involvement in online activities.

Anxiety and depression are reported to be linked with IA. A meta-analysis demonstrated that loneliness and depression were independently correlated to Internet habit. However, this study reported that 90% of the previous studies surveyed use of only either online games or SNS. They also reported that each study targeted only one or two educational stages, for example, junior and senior high schools. It is hard to reveal the relationships among students’ age, types of online activities, mental health, and IA based on past studies, considering likely confounding factors such as cultural background and study designs. Several scales were used to assess IA. Although the Internet addiction test (IAT) is a widely used scale designed to detect realistic disturbances experienced in daily life due to Internet use, previous studies adopted the IAT that varied substantially in scoring methods and cutoff scores. Some studies were conducted online, while others conducted paper-based survey either at the schools or by post. Thus, a systematic understanding of how IA varies among children and young adults is still lacking. To our knowledge, no single study investigated IA comprehensively across students from a whole range of educational stages.

In the present study, we conducted a systematic survey on the severity of IA and factors potentially linked to IA among students with various ages. We recruited 4,119 students from elementary, junior, and senior high schools, and university. We employed the IAT for assessing IA severity, and the K6 scale for psychological distress. We hypothesized that the risk of IA would be modulated by various clinicodemographic factors including type of activities on the Internet, mental health, behavioral pattern of Internet usage, age, and sex. To draw a global picture on the relative importance of these factors, we examined the effects of these factors in a single multiple regression model.

Methods
Participants
A total of 4,119 students participated in this study: 477 (11.58%) elementary school students of fifth and sixth grade from 2 public schools (A and B) and of fourth, fifth, and sixth grade from 1 private school (C), 1,273 (30.91%) junior high school students of first to third grades from 3 private schools, 1,784 (43.31%) senior high school students of first to third grades from 2 private schools (G and H) and 1 public school (I), and 585 (14.2%) university students from 3 public (J, K, and L) and 2 private (M and N) universities.

Ethical approval
The study procedures were approved by ethical committees in Keio University School of Medicine and National Hospital Organization Kurihama Medical and Addiction Center before commencement of the study. All schools and universities that participated in this study were offered a copy of the approved research protocol with the approval number before starting the questionnaire.

Design and measures
The present study was a cross-sectional study based on an anonymous self-report questionnaire. The severity of IA was assessed with the IAT. All the survey procedures were offline, at the schools or universities. The survey comprised four parts:

a) Demographic part: questions on age, sex, place of living, number of family members with whom the participant lived, the number of hours the participant slept daily (hereinafter, sleep duration).

b) Questions about Internet usage: i) the age when the participant was first exposed to the Internet (age of the first Internet exposure); ii) the number of minutes the participant generally used the Internet on weekdays and
holidays, separately (weekday/holiday Internet usage, hereinafter); iii) the activities in which the participant was generally involved while being online (online activities). Following choices were given: online search, Emailing/e-messaging, Internet phone, SNS, online games, downloading (not further specified), watching videos, studying, and online reading.

c) The K6 scale: screening scale for psychological distress consists of questions on six feelings, that is, nervous, hopeful, restless or fidgety, so depressed that nothing could cheer them up, that everything was an effort, and worthless. Participants rated how often they felt each feeling with 5-point scale between none of the time (coded as 0) and all the time (coded as 4). We used a Japanese version of the K6 scale developed by Furukawa et al using the standard back-translation method, and demonstrated equivalent screening performances to the original English versions. A total score of the K6 scale was calculated for statistical analyses.

d) The IAT: a self-report questionnaire with 20 questions on behavioral problems related to excessive Internet use. The participants selected the response from 5-point Likert scale, which was later converted into a number ranging from 1 to 5. IAT total score was calculated by summing up the scores of the 20 questions. A total score of 20 indicated no signs of IA, while a total score of 100 represented the most severe IA. We adopted the following criteria, which were used in previous studies: total scores from 20 to 39 were defined as average usage; scores from 40 to 69 were considered to represent frequent problems due to Internet usage; and scores from 70 to 100 were considered to indicate significant problems caused by Internet usage. Using the above-mentioned cutoff scores, IAT was validated by Widyanto and McMurran, and psychometric properties were analyzed.27

Procedure
We contacted the principals of candidate schools with similar socioeconomic levels and study environment from four prefectures in Japan (Tokyo, Kanagawa, Saitama, and Hokkaido). Nineteen schools and universities were contacted, of which 14 gave consent to cooperate after a thorough explanation on the research protocol was given. After thoroughly explaining the research, parents’ written consent was obtained for elementary and junior high school students. The participants were informed that this study was a survey about Internet usage, that they can decide whether to participate at their own will, and that there would be no disadvantages if they chose not to participate. Students who refused to participate could stay at their places, read something else, study something, or leave the class if they wanted to. They were also informed that there was no correct answer for the questions. Questionnaires were distributed in envelopes and recollected also as such, and the participants were instructed not to talk about the questionnaire with each other in order to avoid biases. No incentives were given to the participants.

Statistical analyses
We analyzed data from a total of 3,224 (78.3%) participants after excluding data from such participants who did not answer all the questions, and those who gave answers that were thought to be inattentive or inconsistent (for example writing the same number to all the questions of K6 scale or IAT, or reporting to use Internet 15 hours per day and sleep 15 hours). The answers to the questions on the eight online activities were treated as binomial variables in the statistical analyses, while the answers for age, number of family members, time spent on the Internet on weekdays and holidays, sleep duration, IAT total scores, and K6 total scores were treated as continuous variables. The names of variables are started with a capital letter hereinafter. Normality of distributions of continuous variables was tested using Shapiro–Wilk test. Then we conducted χ² tests and Kruskal–Wallis tests to detect differences in the categorical and continuous variables, respectively, among different educational stages. Subsequently, as the main analysis, we performed a multiple regression analysis with the IAT total score as the dependent variable to assess the relative importance of the factors surveyed. To avoid the risk of finding spurious effects, we constructed a statistical model as follows: based on the findings of previous studies, age and sex were included. Next, as some online activities were found to be too common or too uncommon among the participants, we limited online activities to be involved in the model so that we included at least 20 male and 20 female participants for any possible combination of the online activities (Figure S1). Then, a multiple linear regression model was constructed with the selected categorical variables and all the available continuous variables as independent variables, and IAT total score as the dependent variable. Low risk of multicollinearity was confirmed with a criterion of variance inflation factor <4. The level of significance was set as 0.05, with a CI of 95%.

The SPSS version 23.0 for iOS was used for the descriptive analyses, and R version 3.5.1 was used for further analysis.
Results
Response rate
The proportion of the participants who answered all the questions was 56.6%, 82.5%, 78.3%, and 86.7% in the elementary schools, junior high and senior high schools, and universities, respectively (Table S1). Cronbach’s α indicated a high level of internal consistency for both the IAT (α=0.898) and K6 (α=0.909) among the whole sample.

Descriptive analyses
The IAT total scores were generally higher among participants at higher educational stages (Figure 1). The correlation matrix between the continuous variables is shown in Table 1. Means, SDs, minimum values, maximum values, and skewness of all the used continuous variables are summarized in Table 2. Shapiro–Wilk test showed that any of the continuous variables cannot be assumed to be random samples from a normal distribution (P<0.001). Accordingly, nonparametric tests were performed in further analyses. Participants who were classified as having significant problems caused by Internet usage were 23.7%, 33.8%, 48.6%, and 56.2% while those classified as with frequent problems caused by Internet usage were 1.9%, 3.5%, 4.1%, and 3.8% among participants in elementary schools, junior high and senior high schools, and universities, respectively.

An increase with age, whereas game users decreased with age, email users tended to increase with age, whereas game users decreased with age, especially among female students (Table 3).

Kruskal–Wallis test provided very strong evidence of a difference (P<0.001) between the mean ranks of at least one pair of groups for all continuous variables. Dunn’s pairwise tests were carried out for all the six pairs of educational stages. The results (see Methods section) were as follows:

Emailing/e-messaging (χ²(3)=284.9, P<0.001), Internet phone (χ²(3)=33.3, P<0.001), SNS (χ²(3)=815.9, P<0.001), Games (χ²(3)=142.3, P<0.001), Blog (χ²(3)=9.5, P<0.05), Downloading (χ²(3)=11.5, P<0.01), Watching videos (χ²(3)=43.5, P<0.001), Studying (χ²(3)=31.5, P<0.001), and Online reading (χ²(3)=13.1, P<0.01). Chi-square tests were performed to test the difference in engagement in online activities between males and females within each educational stage. See Methods section for more details.

Figure 2 shows the participants’ engagement in online activities. Emailing/e-messaging and SNS users tended to increase with age, whereas game users decreased with age, especially among female students (Table 3).

Chi-square tests showed significantly different distribution between educational stages in the usage of Internet for online search (χ²(3)=29.2, P<0.001), Emailing/e-messaging (χ²(3)=284.9, P<0.001), Internet phone (χ²(3)=33.3, P<0.001), SNS (χ²(3)=815.9, P<0.001), Games (χ²(3)=142.3, P<0.001), Blog (χ²(3)=9.5, P<0.05), Downloading (χ²(3)=11.5, P<0.01), Watching videos (χ²(3)=43.5, P<0.001), Studying (χ²(3)=31.5, P<0.001), and Online reading (χ²(3)=13.1, P<0.01). Chi-square tests were performed to test the difference in engagement in online activities between males and females among each educational stage, results of which are indicated in Figure 2.

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stage groups. There was very strong evidence (P<0.001, adjusted using the Bonferroni correction) of a difference between most of the pairs of educational stages in the continuous variables, that is, Internet first exposure, weekday Internet usage, holiday Internet usage, Sleep duration, and K6 total score, whereas significant difference was not found in holiday Internet usage between senior high school and university, Sleep duration between senior high school and university, or K6 total scores between elementary and junior high schools or between elementary and senior high schools. Time spent on Internet on both weekdays and holidays tended to increase with age and sleep duration tended to decrease with age from elementary to senior high schools. K6 total scores were the highest among university students (Table 4 and Figure S2). Mann–Whitney’s U-tests were performed to test the difference in continuous variables between males and females among each educational stage, results of which are indicated in Table 4 and Figure S2.

Multiple regression analyses
Sex, Emailing/e-messaging, SNS, Games, and Study were selected as independent variables in the multiple regression model, while the other binomial variables were excluded because the participants’ responses were highly biased toward either yes or no. A significant regression relationship was found (F(12, 3211)=158.5, adjusted $R^2=0.37$, $P<0.001$) to predict IAT total score (Table 5). The strongest predictive variable was SNS, followed by Games, and K6 total score that reflects psychological distress. One point higher K6 total score predicted 1.06 point higher IAT total score. Next were

Table 1 The correlation matrix between age, number of family members, time spent on the Internet on weekdays and holidays, sleep duration, total scores of IAT test, and total scores of K6 scale

<table>
<thead>
<tr>
<th></th>
<th>IAT total scores</th>
<th>K6 scale total scores</th>
<th>Number of family members</th>
<th>Age</th>
<th>Internet first exposure</th>
<th>Weekday Internet usage</th>
<th>Holiday Internet usage</th>
<th>Sleep duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>IAT total scores</td>
<td>$\rho$</td>
<td>0.476***</td>
<td>0.025</td>
<td>0.269***</td>
<td>-0.002</td>
<td>0.433***</td>
<td>0.458***</td>
<td>-0.244***</td>
</tr>
<tr>
<td>K6 scale total scores</td>
<td>$\rho$</td>
<td>0.476***</td>
<td>0.012</td>
<td>0.259</td>
<td>-0.001</td>
<td>0.194**</td>
<td>0.179**</td>
<td>-0.123***</td>
</tr>
<tr>
<td>Number of family members</td>
<td>$\rho$</td>
<td>0.025</td>
<td>0.031</td>
<td>0.122***</td>
<td>0.001</td>
<td>0.114**</td>
<td>0.092**</td>
<td>-0.078***</td>
</tr>
<tr>
<td>Age</td>
<td>$\rho$</td>
<td>0.269***</td>
<td>0.187**</td>
<td>0.122***</td>
<td>0.001</td>
<td>0.265**</td>
<td>0.449**</td>
<td>0.369**</td>
</tr>
<tr>
<td>Internet first exposure</td>
<td>$\rho$</td>
<td>-0.002</td>
<td>-0.02</td>
<td>0.114**</td>
<td>0.265**</td>
<td>0.091**</td>
<td>0.092**</td>
<td>-0.078***</td>
</tr>
<tr>
<td>Weekday Internet usage</td>
<td>$\rho$</td>
<td>0.433***</td>
<td>0.194**</td>
<td>0.122***</td>
<td>0.001</td>
<td>0.449**</td>
<td>0.369**</td>
<td>-0.336***</td>
</tr>
<tr>
<td>Holiday Internet usage</td>
<td>$\rho$</td>
<td>0.458***</td>
<td>0.179**</td>
<td>0.122***</td>
<td>0.001</td>
<td>0.449**</td>
<td>0.369**</td>
<td>-0.336***</td>
</tr>
<tr>
<td>Sleep duration</td>
<td>$\rho$</td>
<td>-0.244***</td>
<td>-0.123***</td>
<td>-0.078***</td>
<td>-0.336***</td>
<td>-0.114***</td>
<td>-0.269***</td>
<td>-0.261***</td>
</tr>
</tbody>
</table>

Notes: $\rho$: Spearman’s rank correlation coefficient, $P$: $P$-value. *$P<0.05$, **$P<0.01$.
Abbreviation: IAT, Internet addiction test.

Table 2 The descriptive statistics of age, K6 scale total scores, IAT total scores, Internet first exposure, weekday Internet usage, holiday Internet usage, and sleep duration

<table>
<thead>
<tr>
<th></th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>SD</th>
<th>Skewness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>9.00</td>
<td>25.00</td>
<td>15.64</td>
<td>2.75</td>
<td>0.09</td>
</tr>
<tr>
<td>K6 total scores</td>
<td>0.00</td>
<td>24.00</td>
<td>4.77</td>
<td>5.15</td>
<td>1.23</td>
</tr>
<tr>
<td>IAT total scores</td>
<td>20.00</td>
<td>200.00</td>
<td>40.59</td>
<td>13.86</td>
<td>0.83</td>
</tr>
<tr>
<td>Internet first exposure</td>
<td>3.00</td>
<td>18.00</td>
<td>10.21</td>
<td>2.45</td>
<td>-0.35</td>
</tr>
<tr>
<td>Weekday Internet usage (min)</td>
<td>10.00</td>
<td>900.00</td>
<td>162.52</td>
<td>118.51</td>
<td>1.94</td>
</tr>
<tr>
<td>Holiday Internet usage (min)</td>
<td>10.00</td>
<td>960.00</td>
<td>229.57</td>
<td>163.54</td>
<td>1.47</td>
</tr>
<tr>
<td>Sleep duration</td>
<td>240.00</td>
<td>600.00</td>
<td>397.46</td>
<td>62.56</td>
<td>0.30</td>
</tr>
</tbody>
</table>

Abbreviation: IAT, internet addiction test.
Emailing/e-messaging, longer holiday Internet usage, shorter sleep duration, and younger age of Internet first exposure. Study predicted lower IAT total scores.

Discussion
This cross-sectional study based on a self-reported questionnaire investigated the relationships between IA severity and clinicodemographic factors targeting students ranging from elementary schools to universities. This study revealed that (a) the prevalence of IA was 25.6%, 37.3%, 52.7%, and 60% among students in elementary, junior high and senior high schools, and universities, respectively, that (b) use of SNS and Emailing/e-messaging increased with age among both sexes, while Internet gaming generally decreased with age, (c) that Internet usage on both weekdays and holidays increased with age, and that (d) Internet use for SNS and games, severity of psychological distress, Internet use for Emailing/e-messaging, longer holiday Internet usage, shorter sleep duration, and younger age of the first Internet exposure predicted higher IAT total scores in this order, while using Internet for study predicted lower IAT scores.

The results showed that various online activities, prolonged use of Internet, and mental distress are all at least partly independently related to severity of behavioral problems. Involvement of both social services such as SNS and e-messaging, and games was reported in past studies. On the other hand, the present study showed that studying online is negatively linked to IA. Use of the activities positively linked to IA might reflect need in social relationships. Not only SNS and Emailing/e-messaging, but also Internet gaming can reflect needs for social acceptance. Tokunaga reported in his meta-analysis that loneliness and depression were independently correlated to Internet habit. Thus, need in social relationship might be an important driving force in the mechanism of IA. This idea is further corroborated by the present result that educational purposes predicted lower IA severity. Previous studies showed that Internet usage for educational purposes was not related to IA.

These results give us some insight into the mechanisms of IA. The above findings might indicate that psychological urge to socialize rather than achieving concrete purposes plays an important role in IA. Predisposition toward IA may
Table 3 Percentage of students participating in various online activities among different educational stages

<table>
<thead>
<tr>
<th>Educational stage</th>
<th>Sex</th>
<th>Number of participants (mean ± SD)</th>
<th>Online search (%)</th>
<th>Emailing/e-messaging (%)</th>
<th>Internet phone (%)</th>
<th>SNS (%)</th>
<th>Games (%)</th>
<th>Blog (%)</th>
<th>Downloading (%)</th>
<th>Videos (%)</th>
<th>Study (%)</th>
<th>Online reading (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elementary school</td>
<td>M</td>
<td>159</td>
<td>10.76 ±1 0.9</td>
<td>75.0</td>
<td>19.5</td>
<td>82.0</td>
<td>6.3</td>
<td>25.0</td>
<td>0.9</td>
<td>76.7</td>
<td>46.5</td>
<td>13.8</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>111</td>
<td>10.83 ±0.8</td>
<td>81.0</td>
<td>35.1</td>
<td>10.8</td>
<td>7.2</td>
<td>76.6</td>
<td>0.9</td>
<td>65.8</td>
<td>49.5</td>
<td>20.7</td>
</tr>
<tr>
<td>Junior high school</td>
<td>M</td>
<td>134</td>
<td>13.74 ±0.9</td>
<td>92.0</td>
<td>52.2</td>
<td>7.5</td>
<td>35.8</td>
<td>64.9</td>
<td>1.5</td>
<td>72.4</td>
<td>61.9</td>
<td>20.9</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>916</td>
<td>13.52 ±0.9</td>
<td>82.0</td>
<td>70.4</td>
<td>15.8</td>
<td>35.2</td>
<td>45.0</td>
<td>1.5</td>
<td>74.9</td>
<td>46.5</td>
<td>18.0</td>
</tr>
<tr>
<td>Senior high school</td>
<td>M</td>
<td>750</td>
<td>16.71 ±0.9</td>
<td>81.0</td>
<td>70.1</td>
<td>16.1</td>
<td>68.9</td>
<td>74.0</td>
<td>1.3</td>
<td>86.9</td>
<td>45.9</td>
<td>13.7</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>647</td>
<td>16.61 ±1.1</td>
<td>79.0</td>
<td>81.6</td>
<td>13.1</td>
<td>83.9</td>
<td>34.8</td>
<td>0.9</td>
<td>79.8</td>
<td>35.9</td>
<td>12.7</td>
</tr>
<tr>
<td>University</td>
<td>M</td>
<td>195</td>
<td>19.82 ±1.4</td>
<td>88.0</td>
<td>72.8</td>
<td>24.1</td>
<td>78.5</td>
<td>48.2</td>
<td>3.1</td>
<td>82.1</td>
<td>56.9</td>
<td>15.9</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>312</td>
<td>19.64 ±1.5</td>
<td>92.0</td>
<td>82.1</td>
<td>23.1</td>
<td>84.0</td>
<td>30.1</td>
<td>3.2</td>
<td>68.6</td>
<td>53.5</td>
<td>13.1</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>3,224</td>
<td>15.64 ±2.8</td>
<td>83.0</td>
<td>69.4</td>
<td>15.7</td>
<td>57.8</td>
<td>52.1</td>
<td>1.6</td>
<td>78.2</td>
<td>46.3</td>
<td>15.4</td>
</tr>
</tbody>
</table>

Abbreviations: F, female; M, male; SNS, social networking services.

Be facilitated when such urge is met with psychological and cognitive risk factors, such as depression, social anxiety, and maladaptive coping style. 41,42 Personal distress under intense interpersonal settings is demonstrated to be linked to social anxiety and smartphone use disorder. 40 High prevalence of Internet and smartphone use disorder is associated with social anxiety and maladaptive coping style. 41,42 Unsuccessful social relationships may encourage one to revert to virtual relationships online, but worse outcomes for introverts. 39 On the other hand, neuropsychological and neuroimaging studies suggest that IA is linked to functional changes in brain areas such as the prefrontal cortex, possibly related to cognitive risk factors including maladaptive coping styles.
Emailing/e-messaging was positively associated with IA severity. This is also in line with the majority of the previous studies, while one study demonstrated a negative relationship between them. A longitudinal study including 663 students from the Netherlands aged 12–15 years concluded that using chat rooms and instant messengers was positively correlated to the onset of IA and depression 6 months later. As Emailing/e-messaging can be considered as online social interaction media, it is reasonable that Emailing/e-messaging has an effect on SNS severity in the same direction as SNS. Longer time spent online was found to predict both higher IA severity and higher levels of psychological distress. This seems to be natural, because prolonged use of Internet inevitably results in reduced amount of time available for other activities, including spending time with friends and family. This accordingly leads to increased loneliness and depression, and accordingly leads to IA. Eight out of 20 questions of IAT are related to time. The proposed criteria of Internet gaming disorder in DSM-5 include ten items related to time spent on gaming, along with one item related to...
to tolerance. A longer time spent online likely reflects a poorer control on Internet overuse, which could be seen as one characteristic of IA rather than a cause of IA. Tokunaga et al conducted a meta-analysis of 100 studies and the results supported a model conceptualizing IA as a case of deficient self-regulation in which psychosocial problems foster IA and, indirectly, time spent using specific Internet-based technologies.

However, in our analysis, holiday usage but not weekday usage of the Internet predicted higher IA severity. It seems possible that inclination to spend more time on Internet on holidays rather than doing other things is a risk factor, or alternatively indicative of psychological distress or underlying social maladaptation, which increases the risk of IA. It is also possible that excessive use of Internet impairs functioning in other areas of life, which may in turn result in more inclination for Internet usage. Longitudinal research investigating individual’s change in pattern of Internet use, personal achievement, social relationship, mental state, and problems related to Internet use is needed to reveal causal relationship among these factors.

This study revealed that people who started using Internet at younger ages showed higher IA severity, which is in line with previous studies that demonstrated that starting using the Internet at younger age was associated with higher IA prevalence. This finding, together with others, suggests that controlling how young children use the Internet can be beneficial in preventing IA.

Using Internet for study predicted lower IA severity. Students with higher academic performance were reported to have lower IA prevalence, and a longitudinal study reported that self-reported engagement in school activities is a protective factor against IA. Studying online may reflect higher academic performance of the students who try to confine Internet use for study.

Strikingly, age and sex were not suggested to be significant predictors of IA severity. This finding appears to converge with previous studies’ finding that IA is unrelated to neither age nor sex, whereas other studies noted that school grade was a positive predictive factor for IA prevalence. In the present study we found that IA prevalence increased with educational stage, but the effect of age on IAT total score was not significant when the effect of other factors was partialed out. These findings seem to suggest that age may indirectly affect IA severity via other factors including online activities and psychological distress, although the relationship between age and these factors may vary reflecting the characteristic of the population.

The present study found relatively high prevalence of problematic Internet usage. A study in Korea reported that 28.6% of junior high school students were problematic users, while studies in China reported prevalence rates ranging from 10.8% to 21.2%. Although such variability in prevalence may partly reflect true difference between countries, it seems that the variability is largely due to difference in methods as discussed by Kuss and Lopez-Fernandez. They stated that comparisons of current studies are impeded because they significantly differ in the cutoff points used to identify problematic Internet users.

The strengths of this study are as follows: this study was the first survey on elementary school students in Japan. We also comprehensively assessed IA severity and its predictive factors in the wide range of student population. Moreover, we used IA severity instead of IA prevalence to assess the involvement of various factors and found the three online activities closely linked to IA. It should be better to assess risk and protective effects of related factors with IA severity, rather than categorical distinction between normal Internet use and IA.

This study has several limitations. Assessment was based on self-reporting. Insight into participants’ own behavior may have varied among individuals. As the survey was conducted in classrooms, we might have missed students with the highest level of IA who were absent from the class. Other limitation is that we surveyed participants’ involvement in eight online activities, which were not exhaustive. We could not recruit the same number of students from each school. Also, junior high school participants were biased to females, which may have partly affected the results. We could not perform multiple regressions for each educational group separately because of the limited statistical power. In this research, as we did not collect data about the personality traits of the participants, we could not examine the association between IA and personality traits. Causal relationship between mental distress and depression, and IA needs to be investigated in longitudinal studies.

Conclusion
The present study was the first study to assess the relationship between IA and clinicodemographic factors across students of elementary, junior high and senior high schools, and universities. This study noted that IA severity had positive association with SNS use, online gaming, Emailing/e-messaging, and psychological distress.

IA is a new problem for our society, emerging from the rapid development of technology. IA can change its form...
and magnitude over time by its nature. Types and usability of services available online are continuously increasing, some of which may be addictive to some individuals. To maximize the benefit of the Internet while minimizing its negative impact, it is important to continue studies on IA looking at various aspects of Internet usage and its relationships with personal achievement and mental health in various populations. We plan to use the results from this study and continue working with other colleagues in the field to improve the theoretical models for IA.

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Author contributions
ElSalhy conceived of the presented idea. ElSalhy, Miyazaki, Nakajima, Nakayama, Mihara, Kitayuguchi, Higuchi, Muramatsu, and Mimura developed the theory and collected the data. Miyazaki and ElSalhy performed the statistical analyses. Noda and Nakajima verified the analytical methods. Mimura and Muramatsu encouraged for further statistical methods and supervised the findings of this work. Draft was mainly written by ElSalhy, Miyazaki, Noda, and Nakajima after all authors discussed the results. All authors contributed to data analysis, drafting and revising the article, gave final approval of the version to be published, and agree to be accountable for all aspects of the work.

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References


Supplementary materials

Figure S1 Number of participants stratified by engagement in Study, SNS, Games, and Emailing/e-messaging.
Abbreviation: SNS, social networking service.

Table S1 Participated schools and students, and the ratio of participants who fully responded to the questionnaire

<table>
<thead>
<tr>
<th>School</th>
<th>Total</th>
<th>Fully responded</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Elementary</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>122</td>
<td>70</td>
</tr>
<tr>
<td>B</td>
<td>121</td>
<td>81</td>
</tr>
<tr>
<td>C</td>
<td>234</td>
<td>119</td>
</tr>
<tr>
<td>Subtotal</td>
<td>477</td>
<td>270</td>
</tr>
<tr>
<td><strong>Junior high</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>364</td>
<td>296</td>
</tr>
<tr>
<td>E</td>
<td>341</td>
<td>284</td>
</tr>
<tr>
<td>F</td>
<td>568</td>
<td>470</td>
</tr>
<tr>
<td>Subtotal</td>
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<td>1,050</td>
</tr>
<tr>
<td><strong>Senior high</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>J</td>
<td>497</td>
<td>314</td>
</tr>
<tr>
<td>H</td>
<td>341</td>
<td>290</td>
</tr>
<tr>
<td>I</td>
<td>946</td>
<td>793</td>
</tr>
<tr>
<td>Subtotal</td>
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</tr>
<tr>
<td><strong>University</strong></td>
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<td></td>
</tr>
<tr>
<td>J</td>
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<td>29</td>
</tr>
<tr>
<td>K</td>
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</tr>
<tr>
<td>L</td>
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<tr>
<td>M</td>
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<td>46</td>
</tr>
<tr>
<td>N</td>
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<td>295</td>
</tr>
<tr>
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<td>585</td>
<td>507</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>4,119</td>
<td>3,224</td>
</tr>
</tbody>
</table>
Figure S2 Distribution of weekday and holiday Internet usage, sleep duration, and K6 total score of participants stratified by educational stages and sex: four violin plots in each panel correspond to elementary, junior high and senior high school, and university, from left to right.

Notes: The gray area showed smoothed distribution of each variable, where the horizontal width represented relative frequency. White discs indicate the medians, and the thick black vertical lines indicate 25–75 percentile intervals. Results of Mann–Whitney’s U-test between males and females within each educational stage are indicated as follows: ***P<0.001; **P<0.01.

Abbreviations: E, elementary school; F, female; J, junior high school; M, male; S, senior high school; U, university.